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A Review on PCB testing techniques and its Evolution

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Abstract: This paper presents a brief review of different Printed Circuit Board (PCB) testing techniques. It is necessary to detect and diagnosis the faults in PCB as this fault may lead to system failure. Testing is important to ensure proper functionality and quality of PCB. With the development of PCB manufacturing techniques, its testing methods also evolved. The brief history of different testing techniques and its evolution to match with the current technology is studied. With the help of these techniques testing efficiency is increased by reducing test time, cost and increasing test coverage. This paper describes how new testing strategy; Automated Test Equipment (ATE) contribute to low overall manufacturing test costs, quick time to market by improving the fault coverage, reliability and testing time.

Keywords: Printed Circuit Board (PCB), Testing techniques, Automated Test Equipment (ATE)

I. INTRODUCTION

Printed Circuit Board technology has replaced hand wire for more than 60 years ago. Earlier PCBs were assembled manually and tested with the help of simple instruments.

Printed Circuit Board (PCBs) used through hole technologies in 1970`s ; spacing between pins was typically 100 mils, components were only placed on a single side, the largest components rarely had more than 14 pins, the common voltages used to power the boards were 5, 12, and 15 volts[P].

Progress in modern electronics industry involved use of transistors and IC`s on very large scale on PCB. New PCB designs, compact packaging technologies, greater IC integration and functionality, high component density techniques are continuously being introduced. Modern electronics have more complex electronic components and require advanced instrumentation for testing. Integrated circuit (IC) package pin counts have already exceeded 150 and led spacing below 0.635 mm (0.225 in) [1]. So tiny space gives no practical way to implement through-hole/pin-in-hole methods.

This is the reason why through-hole mounted components are being replaced by boards that can utilise surface mount devices (SMDs). It is evident that SMD technology is set to dominate the PCB interconnection scenario for the next decades and beyond. Due to this the electrical and visual access to components on PCB is lost. This makes it more difficult for testing and inspection.

Previously, the unique method used to inspect printed circuit boards was manual testing it involved testing by Manual Visual Inspection (MVI) with the help of multimeters, oscilloscopes and other testing equipment. This method is almost inapplicable for the recent printed circuit, using integrated circuits (ICs) limits the ability of manual testing. Manual testing takes long time to be performed. The efficiency of such diagnose method depends on the repairer knowledge and experience. Hence because of the complexity and the shrinking of electronic circuits, a parallel development in testing methods is highly recommended.

Purpose of testing:

1. To detect defective PCB.
2. To find out which part of PCB is not functioning properly.
3. To avoid defective PCB assembly at Production Line.
4. To avoid Field failure and reloading of finish product.
5. To collect data of faults for analysis purpose.

Generally PCB defects are divided into 3 main categories [1]:

1. **Component faults:** Components fails to meet design specifications.
2. **Manufacturing faults:** Faults caused during manufacturing process like assembly and soldering.
3. **Performance faults:** Caused due to design fault or dynamic device failure.

Two basic test options are used in electronic industries [1]:
Test Process: In this method the system is tested and repaired (if any faults are found) at each and every step during manufacturing process. This ensures no faulty product is conveyed to next step. Hence here the end product has no/zero defect.

Test Product: Here the product is not tested during manufacturing process. Instead directly the final product is tested and faults (if any) are repaired.The graph in Fig.1. concludes that cost is directly proportional to product complexity in *test process*. Hence this method is effectively applicable to complex products. On the other hand simple products are cheaper to test using the *test product* method.

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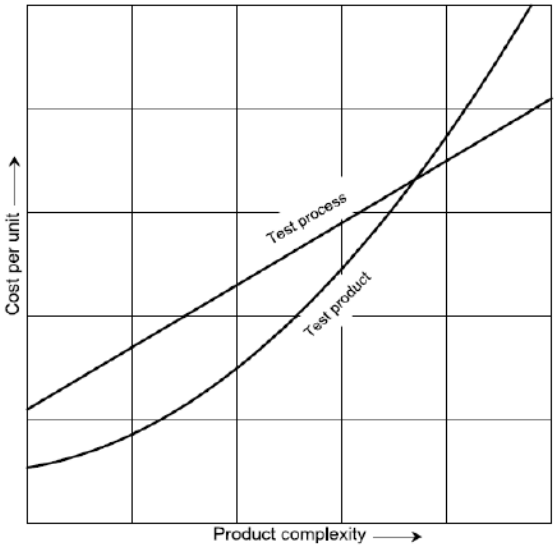

Fig. 1 Test process versus test product [1]

The earlier PCB testing techniques have now been developed and made compatible with the growing PCB technologies. The mass production of complex PCBs can be provided by integrating automated test equipment (ATE) into the manufacturing process. Automating PCB testing processes are now standard solutions for the manufacture of complex electronic products.

II. DIFFERENT TESTING TECHNIQUES FOR PRINTED CIRCUIT BOARDS

The Manual Visual Inspection (MVI) technique has been replaced long ago by various other techniques. Testing techniques are broadly classified into two categories (i) In-Circuit Testing (ICT) and (ii) Functional Testing (FT).

These techniques meet the current requirement of fast growing industrialization and are widely used by the test engineers to locate fault in PCB.

In-Circuit Testing (ICT)

In-circuit Testing [R] technique is most commonly used because it is fast, simple and accurate. ICT uses bed of nails to verify the open circuit, short circuit, resistance, capacitance, missing component on the Board Under Test (BUT). ICT uses too many pins to perform test, this testing technique generally considers the electrical parameters of PCB like current and voltage.

As seen in Fig.2. ICT technique relies on a part of pins that contacts copper traces on PCB under test. By applying predefined set of input signals at these various nodes, corresponding output signals is measured at other nodes of the PCB by another set of pins. ICT verity's each and every component on the board.

With the fast growing technology the size of the components are shrinking and hence density increase on the board. Hence it has become difficult to get physical access to all nodes on the PCB. Another disadvantage of ICT is that the bed of nails design is very costly and can strictly be applied to only one type of PCB.

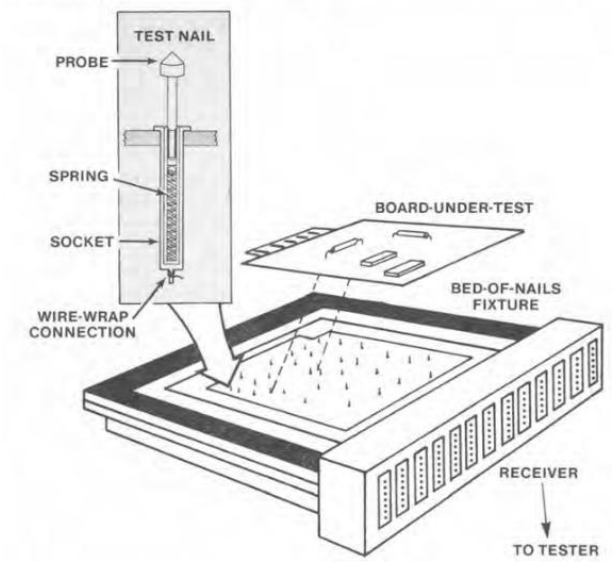

Fig. 2 ICT System with Pins Contacting Board Under Test [8]

Functional Testing (FT)

Functional Testing [1] is method of verifying the functional behavior of the circuit. FT is performed during last phase of production line as final quality control. The PCB is powered up by edge connector and necessary input signals are given and response is measured. It checks whether each block is performing its specified function correctly. The test result is simple pass or fail. Depending upon the complexity of PCB, FT is faster than ICT.

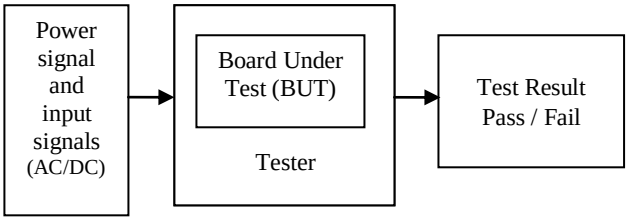

Fig.3 Functional Testing

FT testing is beneficial in today`s world as each and every pin on PCB is difficult to access. Here the system is tested as a whole one unit and final result is given. If the result is fail then it becomes tough to detect where exact the system has failed to work properly. As a disadvantage it can be seen that Functional Testing cannot exactly detect the faulty component or fault location.

III. OTHER TESTING TECHNIQUES

Boundary Scan

Boundary-scan is also known as Joint Test Action Group (JTAG) boundary-scan. It is a method of testing modern (PCBs) after they are assembled. It is used to check pin states, analyze sub blocks in IC or measure voltages. Boundary scan uses the dedicated test logic that is built into many integrated circuits (ICs), to check that each component is correctly inserted and soldered onto the PCB.

In a boundary-scan device, each digital primary input signal and primary output signal is supplemented with a

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multi-purpose memory element called a boundary-scan cell. Each boundary scan cell has four dedicated test access ports (TAP) signals (i) Test Data In (TDI) (ii) Test clock (TCLK) (iii) Test Mode Select (TMS) (iv) Test Data Out (TDO)

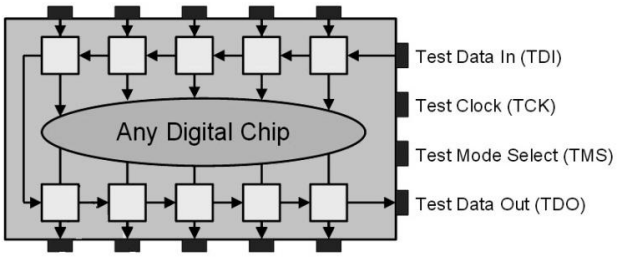

Fig. 4 Boundary Scan Cell

As seen in Fig. 4 these four signals helps to have access to all the pins on the board. Hence boundary scan cell can be thought as virtual nails, having ability to apply test on interconnects structure on boards. With the help of this technique physically inaccessible pins can also be tested. As a disadvantage boundary scan increases the design time and cost because extra four pins are required for testing.

Built-In Self-Test

Built-In Self-Test (BIST) is a design technique that allows a circuit to test itself. BIST architecture requires addition of three hardware blocks to the circuit which is to be tested. The blocks are Test Pattern Generator (TPG), Output Response Analyzer (ORA) and a test controller. The idea is to generate test vectors and give it to Cut and measure the output at ORA.

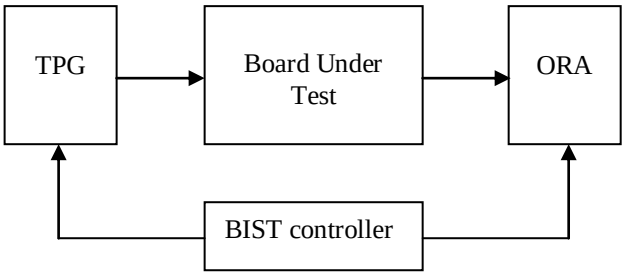

Fig. 5 An overview of BIST

The two common TPG circuits are Pseudorandom Pattern Generator (PRPG) and Shift Register Pattern Generator (SRPG); built using linear feedback shift register (LFSR) and common ORA are Multi-input Signature Register (MISR) and Single-input Signature Register (SISR). Being an automated testing technique it has high fault coverage at cost of area, pin and performance overhead.

Analog Signature Analysis

Analog Signature Analysis (ASA) is a "power off" and direct contact testing technique. In this technique a sine wave (AC) stimulus is applied to a component on PCB and its current flow, phase shift and voltage drop is displayed on instrument by signature display. The current flow causes a vertical trace deflection on the display, while the voltage across the component causes a horizontal trace deflection. This resultant trace on the display is called an analog signature [4].

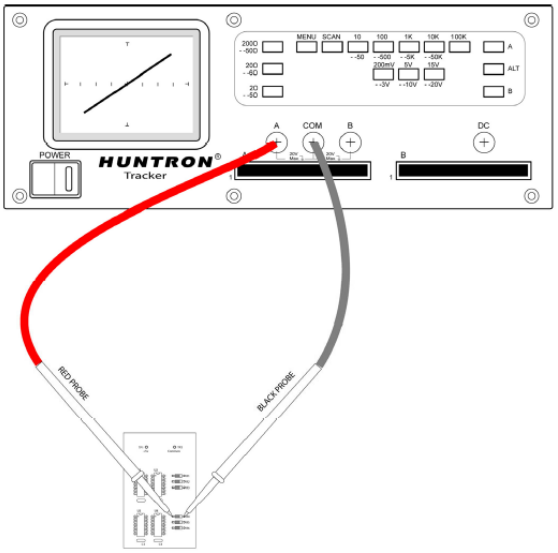

Fig. 6 A typical ASA testing Instrument [3]

Fig. 6 shows a typical ASA instrument while testing a component such as resistor. The red probe connected to channel A and the black probe connected to the common. Analog signature analysis is used for comparison troubleshooting. This means that the signatures of a good printed circuit assembly (PCA) are compared to those of a suspect PCA. Signature differences can indicate a potential problem. In general practice, Channel A is used for the good PCA and the B Channel is used for the suspect PCA.

The main advantage of this method is that doesn't require to power on the device under test, it gives feedback immediately for each component. ASA method has many drawbacks like performing this test for all the PCB components needs long time since it is done manually. It only tests the components and doesn't test any traces between components along the PCB.

IV. SUMMARY OF ALL TECHNIQUES

A brief summary of different testing techniques for printed circuit boards is presented in Table I below.

TABLE I. SUMMARY OF TESTING TECHNIQUES

Technique	Description	Benefit	Drawback
In-Circuit Testing	Uses Bed of Nails	Fast throughput & accurate	Difficult to get physical access to all nodes
Functional Test	Uses Edge Connector	Immediate result as directly fail or pass	Cannot exactly detect fault location
Boundary Scan	Uses boundary scan cells &TAP	Can have access to all pins	Increases design cost and time
Built-In Self-Test	Self-Testing of boards	High fault coverage	Increases pin and area overhead
Analog Signature Analysis	Individual component testing	Doesn't require to power on BUT	Takes too long

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V. NEW APPROACH TO PCB TESTING

Automated Test Equipment (ATE)

During product development phase engineer`s today have quick time to market constraint. Hence it is necessary to reduced production time this can be achieved if testing is automated. It enables very fast and efficient testing method and also gives accurate results in contrast with manually testing. ATE systems are designed to reduce the amount of test time and improve yield by verifying the functionality of PCB and quickly diagnosing the reason of failure and detect faults.

ATE tests perform two basic functions. The first is to test whether or not the BUT is working correctly. The second is when the BUT is not working correctly, to diagnose the reason. An Automatic Test Equipment (ATE) is a system that is composed of test instruments capable of applying stimuli and making accurate measurements under the control of a computer. An ATE can be a simple computer controlled digital multimeter or a set of complicated test instruments that can detect faults in complex PCB. ATE can be used to test wide range of electronic components ranging from simple components like resistor, capacitor, and inductor to Integrated Circuit (IC), Printed Circuit Boards (PCB) and complex electronic systems. ATE reduces the time taken to test the device or to verify if the device is working as per the requirements. ATE quickly finds fault in the DUT if any before it goes to the consumers. According to this method, a number of real instruments such as digital multimeters (DMMs), oscilloscopes, frequency counters, spectrum analysers, etc. are used for testing process. The chosen instruments are mounted into a cabinet, one on top of another, giving the name 'rack and stack'. A computer system, which is used as a controller, is mounted in the some cabinet as the instrument, which in turn are connected to the computer through different types of communication buses.

A number of high speed communication bus technologies have been developed which can be used in ATE as data links and switch interface. Various technologies that can be used for ATE are Serial Rapid 1/0, 10 Gigabit Ethernet, PXI (PCI extension for instrument) [7], Advanced Switching, and Infiniband [6].

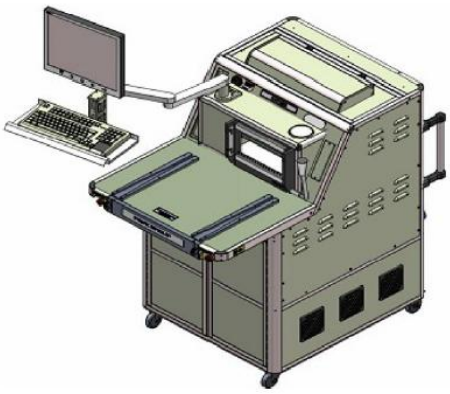

Fig. 6 Automated Test Equipment[1]

Compared with all other bus communication technologies PXI is most suitable in today`s world. The PCI extension for instrumentation (PXI) is an instrument standard which uses a modular instrument system with very fast data interfaces and accomplishes all test and measurement requests. It provides power to all other modules, cooling fans and a very fast PCI bus operating at 33 MHz and 32 bits [1]. The bus topology allows all the devices connected to it to share the same bandwidth. One of the most important characteristics is the 10 MHz system reference clock through which all devices can be accurately timed or synchronised. This allows any instrument to send a trigger signal to another module or multiple modules.

The PXI has become industry standard nearly 1,500 products are available from more than 70 different vendors [1]. Two controller options are available for PXI systems. The first option is to have an embedded controller integrated into the PXI. It is basically a fully working PC in PXI module format and is built using standard PC components offering features such as a hard drive or solid-state drive, RAM, Ethernet, Video, keyboard/mouse, serial, USB and many other elements. The second option is to have an external PC connected to the PXI chassis using a PXI-to-PCI bridge. This second option is more preferable because an embedded controller cannot be upgraded and it is in three times more expensive than an equivalent standalone PC.

VI. CONCLUSION

Various testing methods and their evolution to match the current PCB manufacturing technologies have been discussed here. The drawbacks of previous testing methodology are studied. There`s need of Automated Test methods to cope up with the current market strategies. The key benefits of Automated Test Equipment (ATE) are higher fault coverage, resulting in higher yields, it also provides a good solution when electrical and visual access is reduced.

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